International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

Effect of Friction Pendulum Bearing System on Seismic Performance of Structure

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Abstract**:** ***The current paper investigates the behavior of friction pendulum bearing. Recently developed Triple friction pendulum bearing exhibits as a adaptive in nature for the different level of earthquakes along with its flexibility in design point of view. Different level of earthquakes based on probability of occurrence are considered earthquakes are considered to understand the behavior of TFP bearings. To achieve the target damping ratio and time period, three different models are designed. The influence of increase in displacement shows more effective results in design bases earthquake.***

Keywords **:** ***Seismic Isolation, Triple Friction Pendulum(TFP), Multiple hazard level ground motions.***

I. INTRODUCTION

The Friction type of isolation system is widely accepted now a days due to its adaptive nature. Basically Friction pendulum system is passive type of system, As it does not need any external force for initial activation force by externally. Base isolation filter out the severe ground motions by decouples the super structure and foundation. To avoid the resonance, Isolator increases the overall time period of structure depends on a external ground motions. [1,2,3]

Very novel approach of Friction type of base isolation is Triple Friction Pendulum (TFP) bearing. TFP is very adoptive by having two inner and two of outer sliding surfaces, which gives more displacement capacity and enhance the performance compare to single friction system having one sliding surface. The seismic behavior of TFP for different type of earthquake profiles for probability of occurrence and hazards. [4,5]

II. MATHEMATICAL MODELING OF TFP ISOLATOR

The TFP isolator contains Four Teflon coated concave plates made by stainless steel as shown in Figure 1(a).

Here, radius of curvature for ith concave plate is represented by, R_i, Friction of coefficient is μ_i and displacement capacity by d_i. For modeling purpose, TFP isolator converted in to series model contains spring element for representing restoring force, Gap element for displacement capacity and friction element for friction of each concave plate as shown in Figure 1(b). [6,7,8]

III. METHODOLOGY

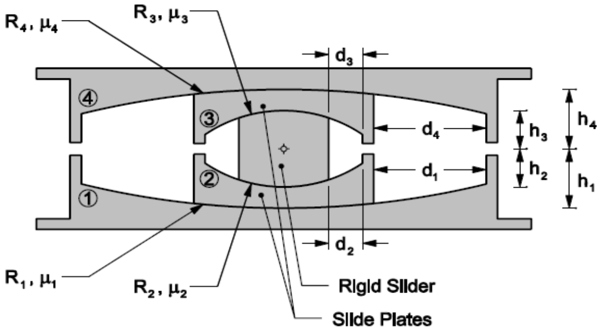
TFP isolator having different damping and force-deformation patters are highly nonlinear compare to rest of the structure. To overcome these difference, step-by-step method of Newmark-Beta in its increment form with small time interval were used to solve governing equation of motion. To analyze the hysteretic model, Fourth-order Runge-Kutta method used. [9,10]

For TFP isolator, Initiation of slider starts from outer lower surface. further as increase in force it softens the isolator and initiate in outer surface. Isolator harden again as motion continuous in inner surface and it stops at the maximum displacement capacity.

IV. PROPERTIES OF TFP BEARING

As per American standards, three different models of TFP were designed for different displacement capacity. To achive target displacement capacity of TFP isolator, curvature radius and friction coefficient were were selected by trial and error method. The detailed design of TFP isolator for target displacement of 0.8m, 1m and 1.2m along with its radius of curvature and friction coefficient for each of the concave plate describe in Table 1. [11, 12, 13]

Properties of building modal fixed based for the analysis are as shown in Table 2.



(a)

Revised Manuscript Received on February 28, 2020.
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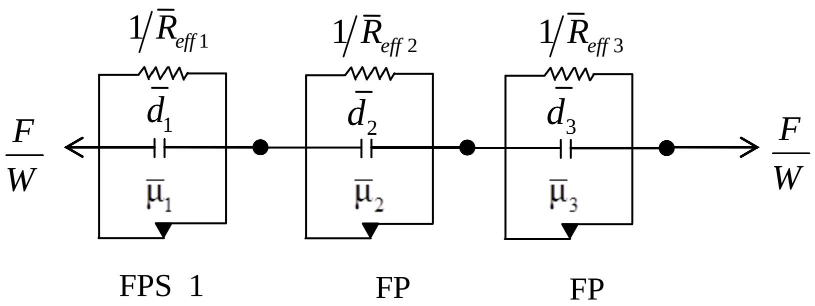

(b)

Figure 1 TFP isolator with its (a) Cross section and (b) Series Model

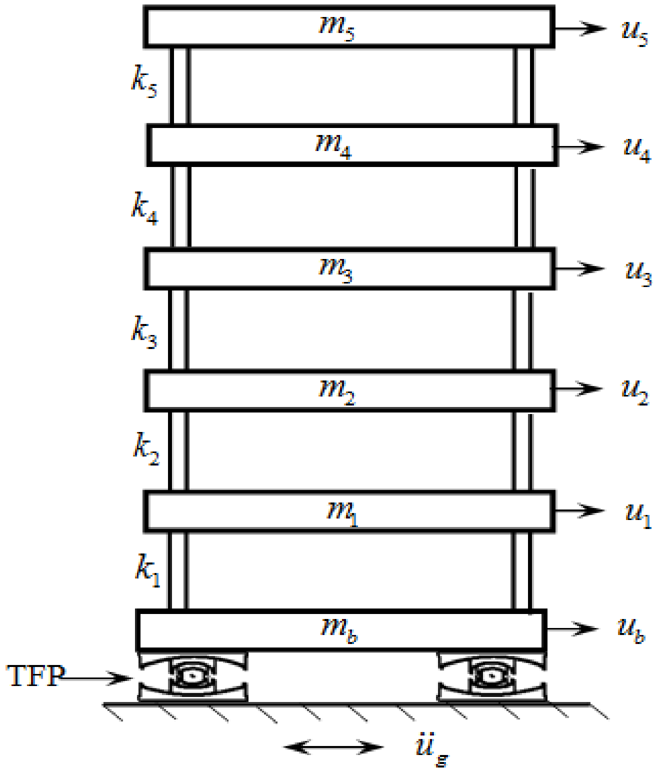

Figure 2 Five-storey building isolated with TFP

Table I: Curvature radius and friction coefficient of TFP isolator

Properties of TFP element						
$R_{\text{eff }1}$	$R_{\text{eff }2} = R_{\text{eff }3}$	$R_{\text{eff }4}$	μ_1	μ_2	μ_3	μ_4
1.6	0.4	1.6	0.045	0.01	0.01	0.04
Properties of FP element of series model						
$\bar{R}_{\text{eff }1}$	$\bar{R}_{\text{eff }2}$	$\bar{R}_{\text{eff }3}$	$\bar{\mu}_1$	$\bar{\mu}_2$	$\bar{\mu}_3$	
0.8	1.2	1.2	0.01	0.08	0.04	

Table II: Properties fixed base five-storey building model

Building with Fixed base	Mode				
Time Period (sec)	0.500	0.171	0.109	0.085	0.074
Modal mass ratio (%)	87.95	8.72	2.42	0.75	0.16

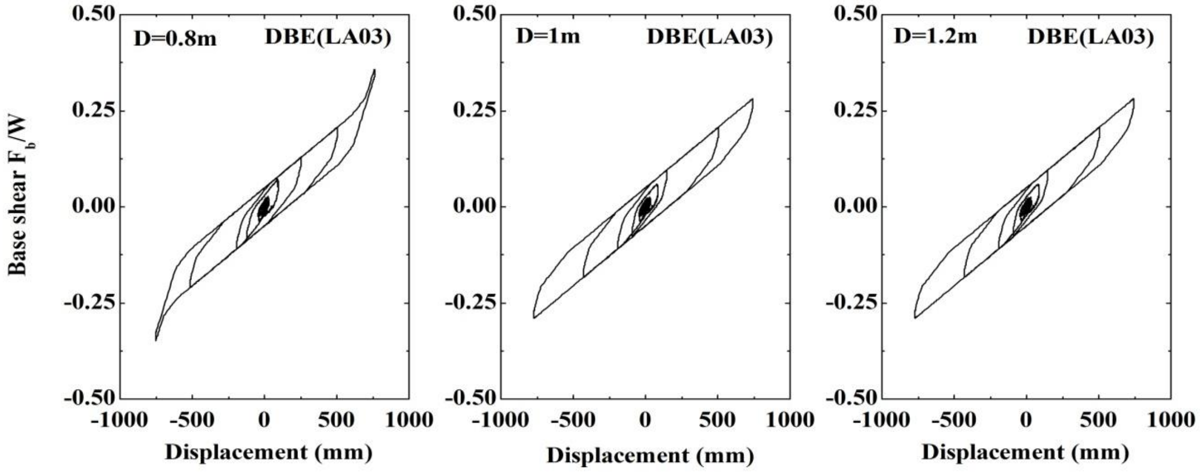

Figure 3 Non-linear force–deformation behaviors of an isolators under LA03(DBE)

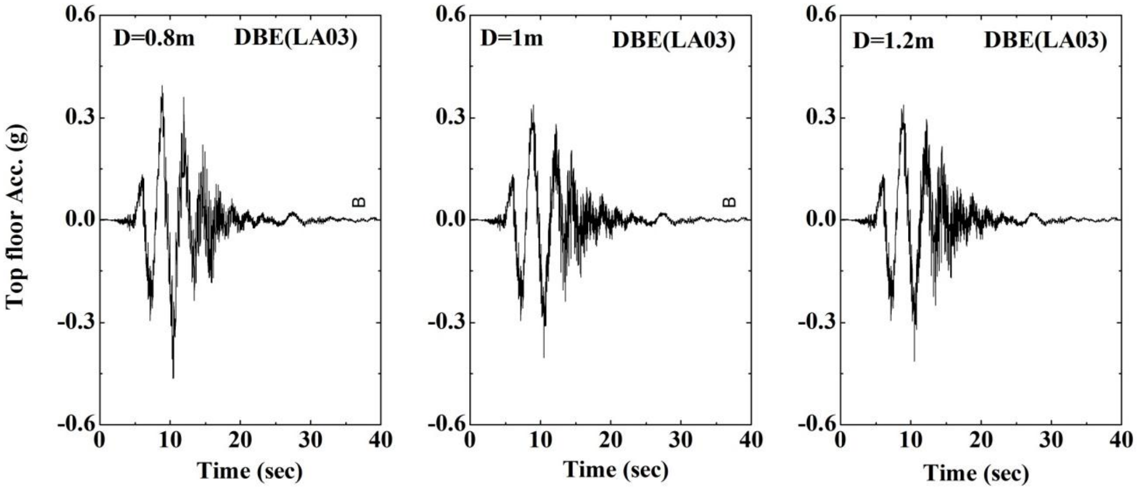

Figure 4 Top floor Acceleration for non-linear hysteretic model of an isolator under LA03(DBE)

Table III: Results of Peak values of Top floor acc, g , Bearing Disp. and base shear, F_b/W

Model	Top floor acc, g	Bearing Disp. (mm)	Base shear F_b/W	Top floor acc, g	Bearing Disp. (mm)	Base shear F_b/W	Top floor acc, g	Bearing Disp. (mm)	Base shear F_b/W
	Disp.=0.8m			Disp.=1.0m			Disp.=1.2m		
FPS	0.281	750.88	0.180	0.214	646.93	0.107	0.182	626.79	0.075
TFP	0.321	714.86	0.189	0.325	616.24	0.114	0.275	634.04	0.084

V. RESULT AND DISCUSSION

To study the adaptive behavior of TFP isolator, seismic response of a five storey building isolated by the TFP isolator is evaluated under different hazard levels with wide variety of frequency content. The hazard level of Design Basis Earthquake Imperial Valley,1979 having Earthquake magnitude 6.5, scale factor 1.01 and PGA 386.04 cm/sec^2 with probability 10% of occurrence in 50 years is considered. [14,15,16]

To study adaptive behaviour of TFP bearing along with comparison of FPS, the example building was subjected to ground excitation of LA03 (DBE). Comparison of force–deformation behaviors for non-linear hysteretic model of an isolators with three different displacement capacities under LA03(DBE) as shown in Figure 3. Top floor Acceleration for non-linear hysteretic model of an isolator with three different displacement capacities under LA03(DBE) as shown in Figure 4. The detail Peak values of Top floor acc, g , Bearing Disp. and base shear, F_b/W for TFP and FPS are as shown in Table 3.

For DBE earthquake, the Top floor acceleration and Bearing Displacement increased for small and medium type of displacement capacity of isolator, It decreases for larger displacement capacity. Base shear decreases continuously as increase in displacement capacity from small to large. Hence, model with medium type of displacement capacity is the optimize for structure isolated with friction type of bearings.

VI. CONCLUSIONS

The following conclusions can be derived for the study:

1. Triple friction pendulum isolator exhibits its adaptive nature by stiffens initially, softens and again stiffens as per inputs of service, design and maximum considered level of earthquakes respectively.
2. base shear decreases and Isolator displacement increases for the Design basis earthquake in case of medium and higher displacement capacity.

3. The values of isolator displacement and base shear are significantly higher for MCE events than SLE and DBE.
4. TFP isolator gives more flexibility to design to control response parameters for different ground shakings, as it contains two inner and two of outer concave plates having total eight parameters including radius of curvature and friction coefficients for each plate.

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